



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

CLINICAL AND EPIDEMIOLOGICAL STUDIES ON EPIDEMIC MENINGITIS

WILLIAM H. ROBEY, JR., M.D. (Boston), Major, M.R.C.
HOWARD L. SAYLOR, M.D. (Dayton), Captain, M.R.C.
HENRY E. MELENEY, M.D. (New York), Captain, M.R.C.
HICKMAN RAY, M.D. (Raleigh), First Lieutenant, M.R.C.
GUSTAV A. LANDMANN, M.D. (Scotland, S. D.), First Lieutenant, M.R.C.

From the Base Hospital, Camp McClellan, Ala.

CLINICAL

WILLIAM H. ROBEY, JR., AND HOWARD L. SAYLOR

The group cases of epidemic meningitis which has occurred at Camp McClellan can in no sense be classed as an epidemic. The 26 cases which were admitted between Sept. 27, 1917, and April 4, 1918, are reported to contrast them with the meningitis cases of other cantonments. The history of the prodromal stage has been obtained in a sufficient number of cases to show great similarity in mode of onset. The majority of the cases began about 3 days before entrance with symptoms of coryza, general aching and stiffness, sometimes digestive disturbances often accompanied with projectile vomiting, and steadily increasing headache. There have been two epidemics resembling influenza in onset at this camp this year, one of which has been recently studied, in which similar prodromata have occurred and cases of meningitis at these times have been overlooked. It has been unusual to have a case of meningitis recognized before entrance. When there is not an epidemic and a regimental surgeon may not see more than 2 or 3 cases at great intervals, it is not surprising that even an increasing headache is overlooked. In every instance, as far as we have been able to discover, there was the history of gradual onset accentuating the belief that the disease is at first systemic and the cerebrospinal inflammation a later development. In not one case was the patient received at the hospital in whom the spinal fluid was not slightly turbid at the first puncture. One patient was in the hospital about 36 hours, being admitted during an epidemic characterized by symptoms suggesting influenza, before a diagnosis was made. The patient's symptoms were not unlike those of several others in the

Received for publication July 26, 1918.

ward except that the headache did not respond to the usual treatment, and there was very slight rigidity of the neck and a suggestive Kernig's sign. It has probably been the failure on the part of regimental surgeons to look carefully for neck rigidity and a beginning Kernig's sign which has delayed admission to the hospital. These two signs are the most reliable guides in distinguishing meningitis from other conditions with similar prodromata. In no case at the time of entrance have they been absent, although sometimes in so slight a degree that unless a careful physical examination was made the condition could be easily overlooked. A rash occurred in only one instance.

In any patient with the foregoing history and even a slight rigidity of the neck and suggestive Kernig's sign, lumbar puncture has been done at once. The fluid was withdrawn under antiseptic precautions and its character and degree of pressure carefully noted. Whether the fluid was cloudy or not, 40 c c of antimeningococcic serum was injected and the fluid in the meantime was sent to the laboratory for study. The injection was repeated in 8 hours and again in from 8-12 hours according to the urgency of the symptoms. Several injections at frequent intervals have generally relieved all symptoms and subsequent treatments have been given at 24-48 hour intervals according to the reappearance of cerebrospinal symptoms. Intravenous treatment has not been used because all our cases had become cerebrospinal in type by the time of admission. Rockefeller Institute polyvalent serum has been used in practically all of the treatments and the response has been immediate in most of the cases. There were a few patients in whom spinal puncture was done with negative results, but one injection of serum was made at the time as a precautionary measure. They are not included in the series since bacteriologic examination was negative and the clinical course was not that of meningitis.

Relapses occurred in Cases 4, 20, and 26. In Case 4, the patient was normal for 1 week and then relapsed. In Case 20, the patient had been normal for 22 days, was free of meningococci, and had been transferred to another ward when all symptoms returned and the spinal fluid became cloudy. Treatment was begun again with excellent recovery. One injection of 40 c c cleared the fluid of meningococci. In Case 26, the patient had a relapse and died after several days. In cases having a poor drainage or a relapse with symptoms of

EPIDEMIC MENINGITIS

319

TABLE 1
SUMMARY OF CLINICAL FEATURES

Case Number	Mode of Onset	Duration at Entrance	Rash	Objective Symptoms	Type of Organism	Spinal Fluid	Treatment	End Results	Remarks
1	10/ 9/17 C.; V.	1 day	None	Loss of consciousness	Meningococcus not determined	Turbidity present	F.R. 92 S. 75	Recovered 11/21/17	Slight deafness
2	10/16/17 Unconscious on admission		None	Delirium; neck rigid	0	Turbid	F.R. 150 S. 150	Recovered 12/7/17	Serum sick
3	10/21/17 H.; V.	2 days	None	Tinnitus aurium; opisthotonus; Kernig; stiff muscles	Meningococcus not determined	Turbid	F.R. .. S. 135	Recovered 1/30/18	Total deafness
4	11/17/17 C.; H. sore throat	3 days	None	Kernig; stiff neck	Meningococcus not determined	Turbid	F.R. 190 S. 140	Recovered 1/28/18	Preceded by talipes equinus and bronchitis
5	11/29/17 V.; H.; abdominal pain	2 days	None	Opisthotonus; Kernig; muscular twitching	Meningococcus not determined	Turbid	F.R. 110 S. 80	Recovered 2/12/18	No sequelae
6	12/22/17 Unconscious		None	Opisthotonus; Kernig; delirium; incontinence of urine; pupils dilated	Meningococcus para	Turbidity pressure+	F.R. ... S. 155	Died 12/24/17	Severe toxemia
7	12/30/17 H.; pain in right knee	2 days	None	Kernig; rigid neck	Meningococcus normal	Turbid	F.R. 190 S. 175	Recovered 2/12/18	Deaf in right ear, improving
8	12/31/17 H.; constipated	3 days	None	Kernig; stiff neck	Meningococcus para	Turbidity pressure+	F.R. ... S. 200	Recovered 2/6/18	No sequelae
9	1/ 1/18 V.; H.; pain in abdomen	3 days	None	Opisthotonus; Kernig; unconscious	Meningococcus normal	Turbidity pressure+	F.R. 195 S. 120	Recovered	No sequelae; preceded by tonsillitis, scarlet fever
10	1/1/18		None	Opisthotonus; Kernig; stupor	Meningococcus para	Turbidity pressure+	F.R. 240 S. 170	Recovered 2/9/18	Diplopia improving
11	1/3/18 V.; H.	2 days	None	Opisthotonus; Kernig	0	Turbid	F.R. 420 S. 320	Recovered 2/7/18	No sequelae
12	1/6/18 V.; H.	3 days	None	Kernig; stiff neck	Meningococcus normal	Turbidity pressure+	F.R. 275 S. 210	Recovered 2/12/18	Diplopia improving
13	1/7/18 H.; V.; stupor	2 days	None	Kernig; neck stiff	Meningococcus normal	Turbid	F.R. 150 S. 120	Recovered 2/15/18	No sequelae
14	1/22/18 H.; V.; stupor	2 days	None	Opisthotonus; Kernig; delirium	Meningococcus not determined	Turbidity pressure+	F.R. 300 S. 340	Recovered 2/12/18	No sequelae; civilian
15	1/22/18 H.; bronchitis	2 days	None	Kernig; unconscious	Meningococcus autopsy			Died 9 hours	Severe toxemia
16	1/24/18		None	Unconscious; Kernig; rigid neck; bronchitis	Meningococcus normal	Turbidity pressure+	F.R. 130 S. 130	Died 1/27/18	Severe toxemia
17	1/24/18 neck stiff; Kernig	2 days	None	Opisthotonus; severe headache	Meningococcus not determined	Turbidity pressure+	F.R. 300 S. 320	Recovered	No sequelae
18	1/26/18 C.; H.; V.	3 days	None	Delirium; Kernig	Meningococcus normal	Turbidity pressure+	F.R. 685 S. 560	Recovered 3/10/18	No sequelae

Case numbers in clinical record do not agree with numbers in laboratory table.
O = chill, V = vomiting, H = headache, F.R. = fluid removed, S = serum in c c.

TABLE 1—*Continued*
SUMMARY OF CLINICAL FEATURES

Case Number	Mode of Onset	Duration at Entrance	Rash	Objective Symptoms	Type of Organism	Spinal Fluid	Treatment	End Results	Remarks
19	1/28/18 C.; H.; V.; tremor	2 days	None	Unconscious; convulsions; opisthotonus; Kernig	Meningo- coccus normal	Turbidity pressure+	F.R. 605 S. 530	Recovered	No sequelae
20	2/11/18 H.; V.; C.	3 days	Hemor- rhagic over whole body	Stiff neck; stupor; Kernig	Meningo- coccus normal	Turbidity pressure+	F.R. 160 S. 200	Recovered 3/12/18	No sequelae
21	2/21/18 H.; V.	2 days	None	Pupils undi- lated; semicon- scious; Kernig	Meningo- coccus not determined	Turbidity pressure+	F.R. 370 S. 240	Recovered	Spinal fluid + after 22 days No sequelae
22	3/19/18 Stiff neck; H.	2 days	None	Very slight Kernig	Meningo- coccus not determined	Turbidity pressure+	F.R. 110 S. 110	Recovered	No sequelae
23	4/9/18 C.; H.; V.	2 days	None	Unconscious; Kernig	Meningo- coccus normal	Turbidity pressure+	F.R. 280 S. 280	Recovered	No sequelae
24	3/24/18 C.; H.; V.; deafness	2 days	None	Unconscious; opisthotonus; deafness; Kernig	Meningo- coccus para	Turbidity pressure+	F.R. 970 S. 640	Recovered in H.	Pericarditis of 8 days' dura- tion
25	1/16/18 C.; H.	4 days	None	Neck and back stiff	Not de- termined	Turbidity pressure+	F.R. 870 S. 620	Recovered	No sequelae
26	4/10/18	5 days	None	Opisthotonus; unconscious; Kernig	Meningo- coccus para	Turbidity pressure+	F.R. 320 S. 240	Died 5/2/18	Relapse 8 days, heart murmur disappeared after 5 days

sepsis the question of ventricular puncture arises. Cases 4, 9, 20, and 26 were patients in whom this form of treatment might have been tried. All patients, excepting Case 26, recovered and without sequelae.

DESCRIPTIONS OF CASES SHOWING UNUSUAL FEATURES

CASE 2.—Patient admitted in wild delirium requiring several men to hold him in bed. There was only slight rigidity of neck and no Kernig signs. About 3 hours after entrance 30 cc of cloudy fluid were withdrawn and an equal amount of serum was given. Two days later the patient was semirational but lay in marked opisthotonos. Five days from entrance perfectly rational, rigidity of neck less but still quite marked. Ten days, the general condition good: slight deafness, right deltoid and pectoralis muscles completely paralyzed and the brachialis anticus weak. Eleven days, marked urticaria and other signs of serum sickness of a few days duration. Recovery from this time was uninterrupted save for the paralyses described which persisted at the time of his discharge from the army, Dec. 7, 1917.

CASE 3.—Admitted Oct. 21, 1917. Taken ill 24 hours before with headache and general aching. He complained of tinnitus aurium at entrance. Conscious but slightly confused. Neck rigid but Kernig sign present. Two days later partially deaf, marked Kernig sign and absolutely deaf. Subsequent course was uneventful except that the deafness persisted: ear drums normal. Total deafness due to involvement of 8th nerve. Discharged from the army, Jan. 30, 1918.

CASE 4.—Admitted Nov. 17, 1917, at 11 p. m. Complained of sore throat and severe headache. For one week before entrance had a coryza and the night before had a chill and could not get warm. There was slight stiffness of the neck and suggestive Kernig sign of both legs; 40 cc of cloudy fluid were removed and 20 cc of serum given. The next day the patient was more comfortable. Meningococci found. The patient improved until Nov. 24 when there was a return of headache and a left orchitis developed. Jan. 6, left parotid enlarged and two days later became bilateral. During this time patient lay in a stupor, lost greatly in weight, and looked as though he was going to die. There was diplopia and deafness but special examinations showed the eyes and ears to be normal. There was incontinence of urine and feces. As late as Dec. 19 the spinal fluid was cloudy. Treatment during the latter part consisted in withdrawal of spinal fluid from time to time. On Dec. 25 there was a sudden cessation of symptoms and recovery was uninterrupted from that time. Discharged to duty Jan. 28, 1918, in excellent condition.

CASE 9.—Admitted Nov. 16, 1917, with tonsillitis. Dec. 1, a moderate course of scarlet fever began. Jan. 1, 1918, the patient was to have been discharged to duty from scarlet fever ward, having been up and in good condition for 2 weeks. The night before he had pain in the abdomen, some nausea, and vomited at 8 a. m. At 9 a. m. he became suddenly unconscious. Supraorbital pressure and pin pricks failed to arouse him. The pupils were equal and reacted normally. It was thought that there might be an embolus. There was slight rigidity of the neck and double Kernig sign was very slight. In 2 days the patient was practically normal again except for a degree of fever when marked rigidity of the neck returned with marked double Kernig sign. Spinal puncture revealed a slightly cloudy fluid under considerable pressure. Meningococci present. For 2 weeks the patient's condition was unfavorable; low muttering delirium with incontinence occurred. Serum given amounted to 120 cc at intervals according to symptoms. On Jan. 9 the temperature became normal and progress was steady from that time. Excellent recovery and returned to duty. There had been no other case of epidemic meningitis in the same ward. Readmitted May 22 with spastic paraplegia manifested by slight ataxia, exaggerated knee jerks, marked ankle clonus and double Babinski. No sphincter involvement.

CASE 20.—This patient was admitted as one of "fever undetermined," yet by the time he was entered at the hospital the ward surgeon had no trouble in making the diagnosis. He was unconscious, with rigidity of the neck and double Kernig sign. Although unconscious at entrance, this man, after 40 cc serum, was sufficiently conscious at the end of 18 hours to tell his name and organization and made an uninterrupted recovery. He was the only patient in the series who showed a rash.

CASE 26.—Five days before entrance on April 10, 1918, this patient felt stiff. Muscles and arms and legs severely stiff; moderate headache; nausea and vomiting of the projectile type. Unconscious at entrance, rigidity of the neck and double Kernig sign. This patient never had a normal temperature except from the second to the fifth day after entrance although there was always more or less opisthotonos. On the 15th, the spinal fluid became clear and except for the opisthotonos the general condition was much improved. On the 22nd, the patient became unconscious again. The spinal fluid ran well at first, then became cloudy, then purulent. Incontinence of urine and feces. The fluid became thicker and harder to withdraw and the back pressure was considerable.

making it difficult to introduce the serum. April 28 and 29 the patient showed marked improvement, regained consciousness, understood and answered questions and took and retained food. On May 1 he became profoundly unconscious and died on May 2.

SUMMARY

Total number of cases, 26; recoveries, 22, or 85%; deaths 4, or 15%.

Total number of cases which received serum treatment, 25, with 22, or 88%, recoveries.

Twelve patients were unconscious on admission or very soon thereafter, of whom 3 died.

Meningococcus, normal type, found in 9 cases; para type in 5 cases, and not determined in 12 cases.

Smallest amount of fluid removed, 90 c c; largest amount, 970 c c; average amount, 325 c c.

Smallest amount of serum injected, 75 c c; largest amount, 640 c c; average amount, 265 c c.

Three cases received more serum than amount of fluid removed: one, F.R., 200 c c—S., 340 c c; one, F.R., 300 c c—S., 320 c c; one, F.R., 480 c c—S., 560 c c.

Sequelae.—Deafness: Four patients, of whom one was total.

Diplopia: Two, both patients recovering rapidly when sent to duty.

Pericarditis: One, who is now recovering in the hospital, but still has rapid pulse.

Paraplegia: One (Case 9), who developed the trouble about a month after being sent to duty.

It will be noted that the prevailing symptoms of onset of disease were a chill or a cold feeling, severe headache which was many times associated with pain in the back and joints, and vomiting of the projectile type. These symptoms always preceded the rigidity of the neck muscles and Kernig's sign and add greatly to the theory that the disease is systemic before the advent of the cerebral and spinal symptoms.

In Case 16, several punctures did not obtain fluid and as these were made high up the necropsy bears out the fact that the seropurulent character of the fluid was responsible therefor. Cases 6 and 15 were no doubt overcome by the severity of the toxemia existent.

As many as 6 cases came from one detachment and the balance of the cases were quite widely scattered over the Division. Meningitis serum was depended on almost solely for results and no sedatives

were given except occasionally to control pain after a puncture and administration of serum. Later some bromids and potassium iodid were given in small doses. Codein was used in preference to morphia and given hypodermatically. Temperatures ranged around 102 F. and higher than 103 F. was exceptional. In all cases, with one exception (Case 23), the pupils were normal in size and reacted very freely to light until the disease was unmistakably established. Several patients complained of photophobia during convalescence and most of them retained some rigidity of the muscles late into convalescence.

EPIDEMIOLOGICAL

HENRY E. MELENEX, HICKMAN RAY,
AND
GUSTAV A. LANDMANN

The occurrence of meningococcus meningitis among the troops at the various army cantonments during the past winter has led to the culturing of a vast number of men for the purpose of detecting the carriers responsible for the spread of the disease. This work has been done in a variety of ways at different cantonments, both as regards technic and the size and character of the groups of men cultured. The types of the disease met with and the extent of the epidemics have also been quite varied. How much all the culturing has accomplished in preventing and checking epidemics is impossible to determine, for the factors entering into the development of the disease in those who acquire the organism in their respiratory passages are as yet but poorly understood. Neither has the organism been finally classified into its various subgroups, nor the pathogenic types separated from the nonpathogenic, if the latter exist. It is, therefore, desirable to record the results of work with this organism in order to help simplify the problems connected with it. At Camp McClellan there have been so far comparatively few cases of meningitis, but a great deal of culture work has been done to detect carriers. It is the purpose now to present (1) some of the results obtained in identifying the various types of meningococcus, and (2) some points of interest in the epidemiology of the subject.

To March 31, 1918, 23 cases of meningococcus meningitis occurred at Camp McClellan; 22 of these received serum treatment; the other

patient died before serum could be administered. Of the 22 treated cases, 19 have already recovered and 1 is convalescent. Two cases were fatal despite several intraspinal treatments with serum. The mortality has therefore been 9.1% in treated cases. In the same period of time 10,076 nasopharyngeal cultures were taken to detect meningococcus carriers, and 934 carriers were found, or 9.3% of the total number of cultures taken. Some men were cultured more than once which would raise the percentage of carriers to total men examined slightly above 10%. Nasopharyngeal cultures were taken on whole companies in which cases of meningitis occurred, and also, after Dec. 30, 1917, on all men who had been away on furlough or who entered the camp as new troops.

METHODS

Culture Medium.—Veal infusion agar, 0.3-0.5% acid to phenolphthalein, with 0.5% dextrose and 5% horse serum added, was used for both plates and slants. This medium was so favorable for the meningococcus that on the plates a 24-hour growth would produce a colony 0.5-1.5 mm. in diameter. When the officer examining the plates became accustomed to their appearance on this medium, confusion with the influenza bacillus, the streptococcus and other organisms was an uncommon occurrence. The use of whole or laked blood for the plates, as is generally advocated¹ instead of serum, was therefore deemed inadvisable, as serum was easier than blood to keep on hand for constant use.

Cultures.—When a case of meningococcus meningitis developed in a certain company, the company was at once placed in quarantine, either in its own company street or in a detention camp. The whole company was then cultured as rapidly as possible, usually all on the same day. After isolating the carriers discovered by the first cultures, one of two procedures was followed. In the early months of our work all the men whose plates contained suspicious gram-negative diplococci which did not agglutinate, were recultured. In the later months this procedure was abandoned, but all men who were tentmates of men discovered to be carriers were recultured, and this process was repeated until no more carriers were found. Despite the high percentage of carriers isolated, we believe that neither of these methods discovered all the carriers in a given company, for some must have escaped detection on the first culture. In the case of men returning from furlough, one culture only was taken.

All cultures were taken by a medical officer from the Base Hospital Laboratory. The West tube swab was used entirely. At first a separate petri plate was used for each culture, but later 2 cultures were taken on a small plate (10 cm. diameter), and 4 on a large plate (15 cm. diameter). It was found that this method, when carefully used, gave results as accurate as with 1 culture to a plate. It is only to be recommended, however, when a very large amount of work has to be done with a minimum of effort, for there is always danger of carrying a few organisms from one side of the plate to the other. After streaking the plate in one small area and around the rim with the inoculated swab, the culture was spread with another sterile cotton swab, which gave a very

¹ Flexner, S.: Jour. Am. Med. Assn., 1917, 69, p. 639.

satisfactory distribution of the colonies for fishing, and a much better distribution than could be secured with a platinum loop. The plates were transported in a large sheet-iron water jacket with compartments for 100 plates. After 24 hours' incubation, all the plates were inspected by one officer. He discarded and reported as negative the plates which contained no suspicious colonies. The remaining plates were then distributed among the officers doing the meningitis work, and the suspicious colonies were transplanted to serum-dextrose-agar slants, usually one colony from each plate. The slants were then incubated for 24 hours, an emulsion in salt solution made of the growth, and a drop of the emulsion stained and examined to prove the purity of the culture.

Agglutination Tests.—For the routine agglutination tests Rockefeller polyvalent antimeningococcus horse serum was used in 1:200 dilution. Mulford's normal horse serum in 1:50 dilution, and normal salt solution were used as controls. The agglutination tests were placed in pans of water in a 55 C. inactivator over night and were read the next morning. For a short period in January a 1:100 dilution of polyvalent serum was used for agglutination tests, but parallel tests with a 1:200 dilution showed that all cultures giving clearcut (2 plus) reactions with the 1:100 dilution, also gave positive reactions (1 plus or 2 plus) with the 1:200 dilution. At that time about 15% of the cultures were giving positive agglutination tests with the 1:200 dilution. This percentage was so high that it was considered probable that the test was identifying all true meningococci, and that the 1-100 dilution was probably agglutinating some organisms which were not true meningococci. The higher dilution was therefore readopted for routine work.

Parallel with the polyvalent agglutinations, monovalent agglutinations with rabbit serum furnished by the Army Medical School against Rockefeller Strains 1 (Normal), 10 (Intermediate A), 30 (Intermediate B), and 60 (Para), were made on 173 cultures. The titer of the 4 serums against their respective organisms was stated by the Army Medical School to be as follows:

Normal (Strain 1)	1:1600
Intermediate A (Strain 10)	1:800
Intermediate B (Strain 30)	1:800
Para (Strain 60)	1:1600

Some of these tests were done with both polyvalent and monovalent serum in 1:100 dilution, some with polyvalent in 1:200 and monovalent in 1:100 dilution, some with both in 1:200 dilution. These different combinations were used in order to determine which would detect the largest number of true meningococci, and at the same time differentiate their types most distinctly.

RESULTS OF MONOVALENT AGGLUTINATIONS

Most of the 173 cultures on which monovalent agglutinations were done, agglutinated with both the polyvalent serum and one of the monovalent serums. There were some, however, which agglutinated with the polyvalent serum, but with none of the monovalent serums, and others which agglutinated with one monovalent serum, but not with the polyvalent serum. Table 1 shows these results.

The first part of this table shows 100 cultures which agglutinated with both polyvalent and monovalent serum; 53 of these were of the

Normal (Strain 1) type, 3 were Intermediate A (Strain 10), 5 were Intermediate B (Strain 30), and 39 were Para (Strain 30). Thus the Normal type is seen to have predominated among the carriers, with the Para type second, and the two Intermediate types quite uncommon. The same proportions existed among the types of organisms recovered from the spinal fluid of our cases, as will be shown later.

TABLE 1
SUMMARY OF POLYVALENT AND MONOVALENT AGGLUTINATIONS

—	Polyvalent + Monovalent +	Polyvalent + Monovalent 0	Monovalent + Polyvalent 0	Totals
Polyvalent 1:100 Monovalent 1:100	22	19	1	42
Polyvalent 1:200 Monovalent 1:100	34	0	7	41
Polyvalent 1:200 Monovalent 1:200	44	34	12	90
Totals	100	53	20	173

The second part of Table 1 shows 53 cultures which agglutinated with the polyvalent serum but with none of the monovalent serums. It will be noticed that all of these occurred when both polyvalent and monovalent serum were used in the same dilution, 19 of them when both were used at 1:100, 34 when both were used at 1:200. In no case did it occur when the polyvalent serum was used at 1:200 and the monovalent at 1:100. These facts suggest that there are some meningococci which were detected more readily by our polyvalent than by our monovalent serum, when both were used in the same dilution, but whose type could be determined if the monovalent serum were used in high enough concentration. It is, of course, impossible to be sure which type these organisms would have fallen into, had we been able to agglutinate them with a monovalent serum. When the polyvalent serum was used at 1:100, some of the organisms which agglutinated may not have been true meningococci. There is evidence, however, that this was not always the case, and that it was the para type of meningococcus which sometimes failed to be agglutinated by the Type 60 (para) monovalent serum. The following points suggest this: Of the 19 cultures which agglutinated only with the polyvalent

serum when all serums were used in 1:100 dilution, 16 were in a series of 35 agglutination tests done on cultures from men in companies where a para type of organism had caused meningitis. Sixteen other cultures of this 35, proved to be para organisms. The remaining 3 were of the normal type. Thus there was a great preponderance of the para type in these companies. Furthermore, 1 culture from which 2 colonies were transplanted, produced from 1 colony agglutination with both polyvalent and para monovalent serum, and from the other colony, agglutination with polyvalent serum alone. Again, 3 men whose cultures in this series contained a para organism, on later culture, when all serums were used in 1:200 dilution, showed an organism agglutinating only with the polyvalent serum. We have noticed also that when agglutination does occur with the para monovalent serum, it is usually much less complete than the agglutination with the polyvalent serum. Although most of this evidence is circumstantial, it points to the fact that the monovalent rabbit serum with which we worked, was less able, in the dilutions in which it was used, to agglutinate all meningococci of the para type than was the polyvalent horse serum. The explanation for this undoubtedly is that the polyvalent serum is from an animal immunized against several organisms of the para type, whereas the monovalent serum is from an animal immunized against the Strain 60 organism alone. Possibly a 1:50 dilution of the para monovalent serum would have agglutinated the organisms which failed to agglutinate with the 1:100 dilution. We tried a 1:50 dilution of the 4 monovalent serums for typing, but found that when this was done the agglutination of many organisms was complete with more than 1 serum, which made it difficult to decide to which type the organism belonged. With a 1:100 dilution, however, a stronger agglutination was always secured with 1 serum than with any of the others, which made that dilution much better for routine work. Our results suggest that possibly a fifth monovalent serum is needed to identify all meningococci in routine army work, or that the Type 60 serum should be replaced by one with better agglutinating power for all the members of the para group.

Now, turning to the third part of Table 1, it will be seen that 20 of the 173 cultures on which monovalent agglutinations were done agglutinated with 1 monovalent but not with the polyvalent serum. Their distribution among the 4 types is shown in Table 2.

TABLE 2
CULTURES AGGLUTINATING WITH MONOVALENT SERUM ONLY

	Normal (1)	Inter- mediate A (10)	Inter- mediate B (30)	Para (60)	Totals
Polyvalent 1:100 Monovalent 1:100	1	+	+	+	1
Polyvalent 1:200 Monovalent 1:100	5	2	+	+	7
Polyvalent 1:200 Monovalent 1:200	10	1	+	1*	12
Totals..	16	3	0	1	20

* Agglutination of this culture was incomplete (one plus).

It will be seen from this table that 80% of the organisms that agglutinated with a monovalent but not with the polyvalent serum were of the normal (Strain 1) type. Unfortunately no series of monovalent agglutinations was done on cultures from a company where a normal type of meningococcus had caused meningitis. It is therefore not known how many carriers harboring this type of meningococcus were missed because of not using the monovalent serums in routine agglutinations. Only 1 culture failed to agglutinate with polyvalent serum when it was used in 1:100 dilution, showing that that dilution identified nearly all true meningococci, but we suspect that this dilution also agglutinated some organisms which were not true meningococci. The most interesting point brought out by this table, however, is that it was almost invariably the normal type of meningococcus which was found when the monovalent rabbit serum produced agglutination and the polyvalent horse serum did not. We cannot assert that this shows any weakness of the polyvalent serum against meningococci of the normal type, although we at first failed to get polyvalent agglutination of 1 spinal fluid organism from a fatal case (Case 6), even in a 1:100 dilution of the serum. All we can say is, that whatever it is that interferes with agglutination by the polyvalent serum, interferes with organisms of the normal type, not with those of the para type.

Another point of interest in connection with these monovalent agglutinations is the cross-agglutination which frequently occurs. Used in either 1:100 or 1:200 dilution, most organisms which are agglutinated by the normal (Strain 1) serum are also, to a lesser

degree, agglutinated by the intermediate B (Strain 30) serum. And most organisms which are agglutinated by the para (Strain 60) serum are also, to a lesser degree, agglutinated by the intermediate A (Strain 10) serum. In our work we have classified the various organisms according to the type of serum with which the most complete agglutination was produced. The difference has always been distinct enough in the 1:100 dilution of the serum to leave no doubt in our minds to which type a given organism belonged. This power of cross-agglutination suggests that the so-called normal type and the intermediate B type are closely related, and that the intermediate A type and the para type are likewise closely related. If this is true the present nomenclature does not accurately express the relationship of the 4 strains of meningococci, and the 2 intermediates should be reversed.

VARYING AGGLUTINABILITY OF ORGANISMS

We frequently found that different cultures from the same carrier, or even different colonies from the same plate, varied in their agglutinability with polyvalent and monovalent serum. This occurred in spite of the fact that the technic of running through the tests was as uniform as possible, and the gross and microscopic appearances of the cultures were similar. Examples of this among the para group of organisms were cited in the foregoing. Similar examples were observed among the normal type. It is interesting to note, however, that where the agglutinability varied in an organism of the para type, it was always the para monovalent serum which failed to agglutinate, when the polyvalent serum did agglutinate. On the other hand, when the agglutinability varied with an organism of the normal type, it was always the polyvalent serum which failed to agglutinate, when the normal monovalent serum did agglutinate.

An example of this variability was met with in the spinal fluid organism from the fatal case of meningitis mentioned above (Case 6). This organism at first failed to agglutinate with the Rockefeller polyvalent serum even in a 1-100 dilution, although agglutination was produced by the normal monovalent serum in 1-400 dilution. The organism was sent to Dr. Olitsky at the Rockefeller Institute, who succeeded in agglutinating it from a subculture on plain dextrose agar, by the Rockefeller polyvalent serum in 1:200 dilution, as well as by the normal monovalent serum in 1:400 dilution. We also succeeded, after several generations of subculture, in agglutinating it from serum-

dextrose-agar with Rockefeller polyvalent serum in 1:200 dilution. Repeated transplantation apparently increased the agglutinability of the organism. Whether the presence of the horse serum in the medium with which we worked had anything to do with this varying agglutinability we do not know. With our volume of work it was impracticable to use any other kind of serum for our medium or to do our agglutinations on cultures grown on plain dextrose agar.

SUMMARY OF MONOVALENT AGGLUTINATIONS

Summing up our observations on monovalent agglutination tests, we would emphasize the following points:

1. A potent polyvalent antimeningococcus horse serum in 1:100 dilution will identify nearly all true meningococci, but may agglutinate some organisms which are not true meningococci.

2. Four monovalent antimeningococcus rabbit serums, against Normal, Intermediate A, Intermediate B, and Para strains, respectively, if used in strong enough concentration, will probably identify all meningococci, but a 1:100 dilution is the strongest which will easily differentiate between the types, and this dilution fails to agglutinate some true meningococci.

3. Some normal type meningococci agglutinate more readily with the monovalent than with the polyvalent serum,* and some para type meningococci agglutinate more readily with the polyvalent than with the monovalent serum.

4. It is therefore suggested that to obtain the most accurate results in identifying and typing meningococci from the nasopharynx, a polyvalent horse serum in 1:200 dilution and 4 types of monovalent rabbit serum in 1:100 dilution should be used.

THE RELATION OF CASES TO CARRIERS

The relation of the meningococci from our cases of meningitis to the meningococci from the carriers in the companies in which the disease occurred, is shown in Table 3. Only the cases in which the organism causing the disease was typed are included in this table. In the 11 other cases of meningitis, either no organism was recovered on culture of the spinal fluid, or, if recovered, the organism was not typed.

This table, although very incomplete, is quite definite as far it goes. It will be seen that all the cases of meningitis occurring in the 112th

Heavy Field Artillery, whose organisms were typed, were caused by a meningococcus of the para type, while all the other cases except one, whose organisms were typed, were caused by the normal type. The companies from which Cases 2 and 3 came are the only ones on whom a regular series of monovalent agglutinations was done. The table shows very definitely the predominance of the para type of meningococcus in these companies. It is unfortunate that no series of monovalent agglutinations were done on cultures from companies in which the normal type had caused meningitis. It is probable that in these companies the normal type of meningococcus predominated.

TABLE 3
MENINGOCOCCI FROM CASES AND ASSOCIATED CARRIERS

Lab. Case No.	Co.	Regt.	Spinal Fluid Organism	Organism from Carriers					
				Normal (1)	Inter. A (10)	Inter. B (30)	Para (60)	Poly + Mono 0	Mono + Poly 0
1*	A	112 HFA	Para						
2	E	112 HFA	Para				14	1	
3	Sup	112 HFA	Para	3			8	1	1
5*	A	104 MP	Para						
6	C	111 FA	Normal	1		1			
7	4	104 AT	Normal		1			1	
10*	D	116 Inf.	Normal						
12	I	116 Inf.	Normal	1					
14	D	104 Eng.	Normal	2			1	1	
15*	E	104 Eng.	Normal						
19*	..	113 Amb.	Normal						

* No monovalent agglutinations done.

An attempt has been made to connect each case of meningitis with the presence of a chronic meningococcus carrier who was in direct contact with him. This has been possible to a considerable extent, as is shown in Table 4. Only the most chronic carrier in each company, or more transient carriers who were in close contact with the cases, have been entered in this table.

It will be noted that 14 of the 23 cases came into direct or indirect contact with a carrier who continued to harbor the meningococcus for over a month after detection, despite the spraying of his nasopharynx with an antiseptic 4 times a day. Six of the cases came into frequent direct contact with these chronic carriers, and Cases 16 and 17, which started within a week of each other, were in direct contact with the same chronic carrier. This evidence seems to point definitely to the chronic meningococcus carrier as the source of this series of cases.

TABLE 4
RELATION OF CASES TO CHRONIC CARRIERS

Lab. Case No.	Co.	Regt.	Spinal Fluid Organism	Carrier in Contact			Duration of Carrier State
				Carrier No.	Origin	Degree of Contact	
1	A	112 FA	Para	207	?	None known	43 days
2	E	112 FA	Para	{473 156	Para ?	None known Tent mate	34 days* Less than 17 days
3	Sup.	112 FA	Para	309	?	Tent mate 2 weeks	53 days
4	Hdq.	112 FA	?	113	Para	Tent mate 1 week	90 days†
5	A	104 MP	Para	No carriers detected			
6	C	111 FA	Normal	490	Normal	Next tent, friend	17 days
				{189 243	? ?	None known Tent mate	63 days 35 days
7	4	104 AT		227	?	Tent mate	Less than 21 days
8	A	116 Inf.	?	184	?	Visited tent	51 days
				{0	?	Case=Clerk of Co.	
9	C	116 Inf.				Carrier=Capt.	19 days
				153	?	None known	29 days
10	D	116 Inf.	Normal	—	—	—	—
11	F	116 Inf.	?	66	?		40 days
12	I	116 Inf.	Normal	120	Normal	None known	89 days†
13	M	116 Inf.	?	{104 322	? Normal	None known None known	65 days 28 days*
				657	Normal	None known	42 days
14	D	104 Eng.	Normal	{193 195	? ?	Tent mate Tent mate	7 days 7 days
15	E	104 Eng.	Normal	Company not cultured			
16	309	Bakery	?	190	?	Cpl. of squad	64 days
17	309	Bakery	?	190	?	Cpl. of squad	64 days
18	B	113 Inf.	?	130	Normal	None known	45 days*
19	113	Amb. Co.	Normal	{603 604	? ?	Next tent Company barber	26 days 17 days
20	H	114 Inf.	?	758	Normal	None known	38 days†
21	I	114 Inf.	?	Company formed only 5 days before onset			
22	..	3rd. FA	Normal	Case imported†			
23	—	—	?	Case a civilian carpenter			

* Meningococcus again obtained from carrier, April 3, 1918.

† Carrier not yet released from quarantine.

‡ Case found to be a meningococcus carrier on return from furlough following recovery. Had had 3 negative nasopharyngeal cultures before discharge from hospital. Carrier organism also of normal type.

There is not space in this paper for a detailed discussion of the chronic meningococcus carrier in his relation to cases of meningitis. The subject is one which needs considerable study. The carriers at Camp McClellan were isolated in a quarantine camp and were sprayed by way of the nose and mouth 4 times a day. Both dichloramin-T and carbolized solution of iodine, N. F. (Boulton's solution) were used for the spray. One worked about as well as the other. Some carriers cleared up quickly; others seemed to be unaffected by the treatment. Sunshine and warm fresh air apparently did more than spraying to rid the nasopharynx of the meningococcus. Cultures were taken at 3-day intervals and the carrier released after the third consecutive negative culture. The men were not sprayed within 12 hours before a culture was taken. We were not convinced that this procedure

would permanently rid the chronic carriers of the organism, so about a month after their release from quarantine 30 of the most chronic carriers were recultured, and 12 of them, or 40%, were found still to harbor the meningococcus. It is therefore evident that 3 consecutive negative cultures at 3-day intervals did not insure the permanent clearing of the nasopharynx. Either a longer interval or more negative cultures, or both, should be required. We are of the opinion that more cultures rather than a longer interval would produce the best results, say 5 cultures at 4 or 5-day intervals. We also believe that each chronic carrier should be followed after his release by a "register" similar to that given to malaria patients in the army, so that cultures could be taken at definite intervals, or whenever the carrier entered a new command.

WEATHER CONDITIONS AND THE MENINGOCOCCUS

Most of the cases of meningitis at Camp McClellan during the past winter occurred in January. The highest percentage of carriers as well as the largest number of carriers were also detected during that month. In this region of the country, as everywhere else, the most severe weather of the winter also came during January. We obtained the monthly records of temperature and rainfall for this locality from the U. S. Weather Bureau in Anniston, Ala., and the relation between these weather conditions and the prevalence and activity of the meningococcus is shown in Chart 1.

It will be seen from this chart that during the first 3 months the percentage of carriers among contacts increased more than the number of cases. This may be ascribed to the continued close contact of the troops in their quarters as the weather grew colder. The organism was gradually being passed from one man to the next. During these months the rainfall averaged between 1 and 2 inches per month, and much outdoor training was possible. In January, however, with but slight decrease in the mean temperature, there was an increase of rainfall to over 8 inches, and a coincident marked increase in the number of cases of meningitis and of the percentage of carriers. Then with the return of fair, warm weather early in February, both cases and carriers again fell to a very low number. Apparently the close contact of the troops in tents and mess halls during the inclement weather was an important factor in the rapid spread of the meningococcus. This undoubtedly applies to the spread of all other respiratory infections as well.

CULTURING OF MEN FROM FURLOUGH

All men returning from furlough since Christmas have had nasopharyngeal cultures taken for meningococcus. This work was done on the assumption that these men might pick up meningococci on trains or at home, and start an epidemic on their return to camp. Of these furlough men, 5,717 were cultured up to March 31. These

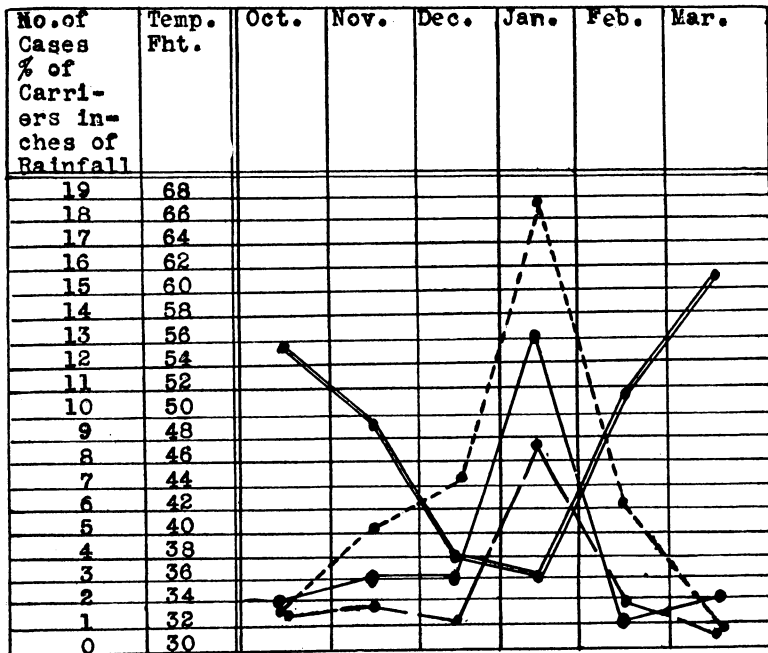


Chart 1.—Relation of weather conditions to the prevalence of the meningococcus and the occurrence of meningitis.

- = Cases of meningitis.
- - - - = Percentage of contacts* found to be carriers.
- = Rainfall in inches.
- = Mean temperature — Fahrenheit.

* Contacts are members of companies in which cases of meningitis occurred.

men had all been in camp for several months before their furlough, and were on furlough for about a week. On their return they were placed in an isolation camp until their cultures were reported. Some were from companies in which cases of meningitis had occurred, but most were not. These men, therefore, represent a good average of the whole camp for the occurrence of meningococci. Chart 2 shows

the relation between the percentages of carriers among furlough men and in companies in which cases of meningitis had occurred.

The striking point brought out in this chart is the greatly higher percentage of carriers among contacts than among furlough men during the month of January. This coincides with what has generally been found elsewhere in both civil and military populations.² That the percentage of carriers among furlough men was higher in

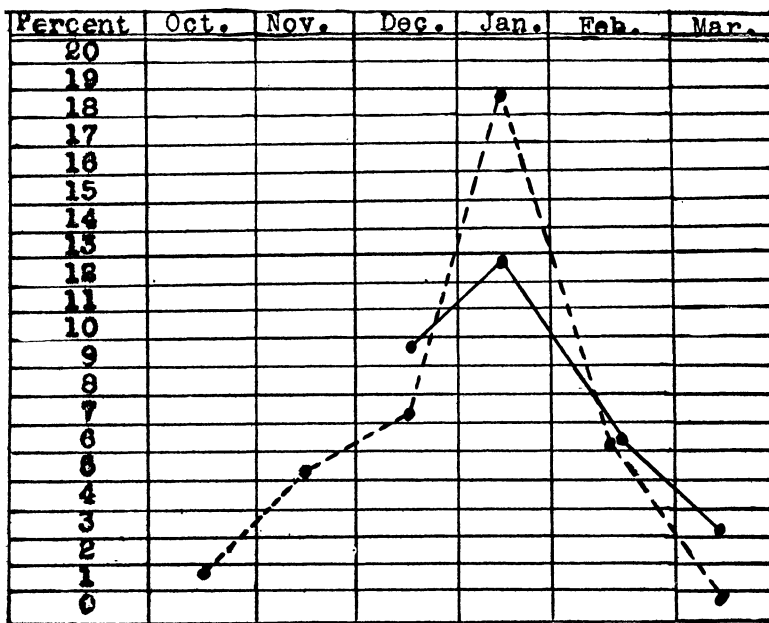


Chart 2.—Carriers among furlough men and contacts.

Solid line = Per cent. of carriers among men returning from furlough.

Dash line = Per cent. of carriers among companies in which meningitis occurred.

December and March than among contacts can be explained. In December all the cultures on furlough men were taken on the last 2 days of the month, that is, very close to the high-rate month of January. The contacts, on the other hand, were cultured at intervals during December. In March one of the contact companies cultured was a troop of mounted military police, who are never all in their quarters at the same time, and in which a small percentage of carriers would therefore be expected. No carriers were found in this company.

² Medical Research Committee (English), Special Report Series No. 3.

One purpose which the culturing of the men returning from furlough accomplished, however, was that it definitely freed them from the suspicion of being the cause of the sudden increase in the number of cases of meningitis in January. Had they not been cultured, they would undoubtedly have been suspected of being the source of these infections.

One other point of interest in our work deserves mention. In only one instance did a second case of meningitis occur in a company in which one case had already occurred and the carriers had been separated.* This one instance occurred in April, 3 months after the company was cultured. The first case was caused by a para type of meningococcus, the second by an intermediate B. Neither did a case of meningitis occur among any of the men isolated as carriers. In other cantonments, where definite epidemics of meningitis have occurred during the past winter, cases have appeared among men already isolated as carriers. This forces us to the conclusion that our apparently good results have been due not so much to the large number of carriers isolated as to the fact that our cases were probably a series of sporadic infections rather than an epidemic of meningitis.

CONCLUSIONS

1. The use of a good polyvalent antimeningococcus serum together with 4 types of monovalent serum for agglutination tests, detects more accurately all types of meningococci, in routine work on a large scale, than does either polyvalent or monovalent serum used alone.

2. Most of the meningococcus carriers in a company in which a case of meningitis occurs, harbor an organism of the same type as that causing the case of meningitis.

3. It is usually possible to find a chronic meningococcus carrier in a company where a case of meningitis occurs.

4. Three consecutive negative cultures taken at 3-day intervals does not insure permanent freedom of a carrier from the meningococcus. At least 5 negative cultures should be required, and the carrier cultured at intervals after release.

5. The meningitis at Camp McClellan during the past winter is considered to have been a series of sporadic cases, not an epidemic.

* Cases 16 and 17 (Table 4) both came from the same company, but both occurred before the company was cultured.